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Microgravity Science Glovebox

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MICROGRAVITY SCIENCE GLOVEBOX

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Abstract

The Microgravity Science Glovebox is a versatile research facility designed to permit the flexibility of crew manipulated investigations on the International Space Station (ISS). The MSG configuration has been planned around the concept of an experimental workstation where a variety of experiments can be installed and operated in a fashion very similar to their operation in a ground-based laboratory. The approach has been to provide a large working volume with a significant set of power, data and imaging resources, all enclosed, but accessible by the crew through sealed glove ports. This arrangement allows the advantage of interactive experimentation without unduly compromising the experiment design with restrictions imposed by protective and containment challenges that normally arise in manned space-flight laboratories. In addition, the data and imaging resources allow cooperative monitoring of experiment progress between the crew and ground-based scientists. As ISS utilization evolves, the MSG is scheduled to become a major pathfinder for developing and exploiting the scientific advantages of truly enabling the coupling of experimentation in space with an evaluative response from the crew and investigators.

Introduction

The Microgravity Science Glovebox (MSG) is a joint development project between NASA and the European Space Agency (ESA). It is a versatile facility designed to accommodate substantial experimental hardware in an interactive configuration. The approach allows for crew setup, operation and monitoring with participation from ground-based investigators via data and video links. The facility has been designed to provide resources and support for the entire set of subdisciplines in the microgravity program; materials science, biotechnology, fluid physics, combustion, and fundamental physics. Specifically, the facility provides a large enclosed work volume, power, data, video, vacuum connections, heat rejection, stowage, filtered air, gaseous nitrogen, lighting and physical positioning and hold-down attachments. The system is designed around the concept of a versatile and multiple function workbench for performing investigations that require the microgravity environment of the ISS and the advantage of crew operation.

Previous gloveboxes include the NASA Spacelab Glovebox, the NASA Shuttle Middeck Glovebox, and the MIR Glovebox. The Middeck and MIR gloveboxes are essentially identical in design and function. The MSG is the evolutionary follow on of these two previous gloveboxes providing a number of enhancements over its predecessors. It has the resources to conduct extremely complex and comprehensive scientific activities but remains very user friendly and easy to use for simple tasks. Enhancements include:

- Larger work volume
- Larger ports
- Increased power for investigations
- Increased thermal heat removal for investigations
- Increased work volume illumination
- Significantly advanced data system with real-time downlinking and uplinking
- High quality video system
- Ground commanding of facility and investigations

See Figure 1.0 for a graphical drawing of the MSG.

Microgravity Sciences Investigations

Investigations for gloveboxes are selected through a proposal review process. Candidates for proposals are investigators that have been previously selected through the NASA Microgravity Research Announcement program (NRA). The glovebox investigations must support the research that has been approved for each investigator through the NRA program. The major science research disciplines supported by the microgravity program are materials science, biotechnology, fluid science, combustion

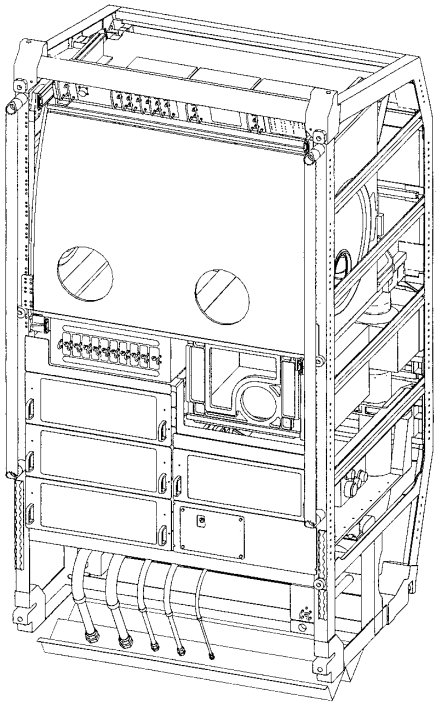

Figure 1.0 Microgravity Science Glovebox (MSG)

science, and fundamental physics. In the past, these investigations have been small because of limited capabilities of the Spacelab and Middeck gloveboxes. However, the glovebox program gives the investigator access to microgravity conditions that can significantly benefit the main area of their NRA research. Fundamental concepts can be tested before a full flight experiment program is developed. Past glovebox investigations have included:

Fluid Interfaces
Thermocapillary flow
Protein crystal growth
Fiber pulling
Containerless processing
Soot formation
Solution crystal growth
Particle dispersion
Combustion physics
Bubble dynamics
Thermal diffusion

MSG Facility System Concept

The main element of the MSG is the core facility. It is a large sealed enclosure mounted on four sliding rails that enable it to be retracted and extended from within the rack. The retracted position (fully pushed into the rack) is for crew unattended operation and when deactivated. The unattended retracted position is used to minimize the amount of vibration imposed on the investigations inside. The deactivated retracted position removes any obstruction of the cabin aisleway. The extended position is for crew attended operation including loading investigations and normal glove port activities. The extended position provides access to the large side ports that can be opened for setup tasks. The extended position also allows the crew person to place their knees under the work surface much like sitting at a table. Most of the resources provided for the investigation hardware are located inside the work volume. An airlock is attached directly to and under the work volume for transferring items into and out of the work volume. Stowage for facility ancillary equipment such as spares and consumables is provided in drawers under the work volume. See Figure 2.0 and 3.0 for graphic drawings of the core facility.

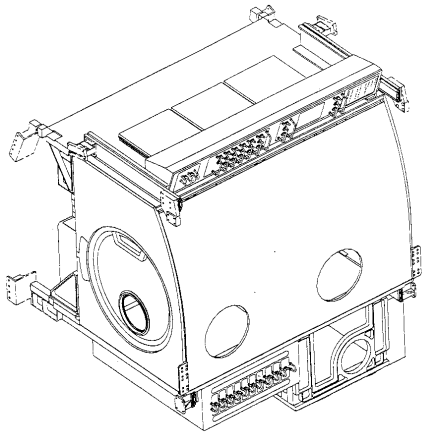

Figure 2.0 MSG Core Facility

MSG Subsystems

Rack

The rack is an IHI NASDA international standard payload rack (ISPR). It has been modified and strengthened to accommodate the large work volume. It is an all-aluminum structure.

Work Volume

The work volume is the main element of the MSG core facility. It is a large sealed and environmentally controlled enclosure with access ports, windows and glove ports to contain investigations that require

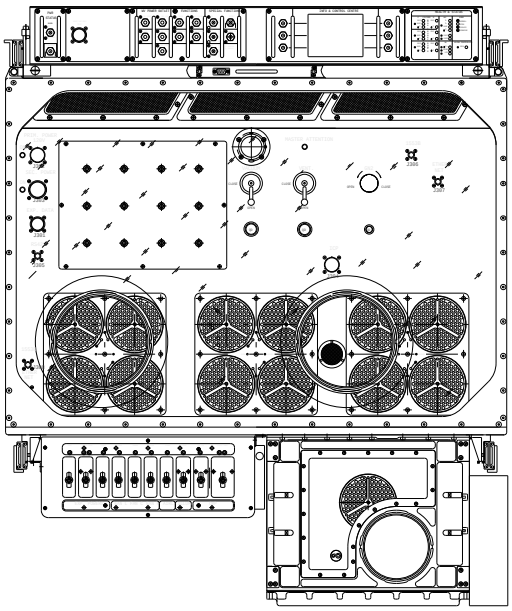

Figure 3.0 MSG Core Facility

multiple levels of contained isolation from the crew and the ISS module cabin.

Containment

The work volume is designed to provide two levels of containment for investigations. The first level is by the physically sealed structure of the work volume. The second is from the negative pressure induced by the filtered air system.

Ports

Two glove ports are located on the front Lexan window of the work volume. They are the main ports used by the crew to perform gloved operations inside the work volume. On each side of the work volume is a large removable access port for loading, unloading and initial setup of investigations. These ports are 406 mm in diameter. A glove port is also located in each side access port.

Window

The front of the work volume is a large observation window made of Lexan. It is scratch resistant coated. The window is curved inward at the top to provide more strength for the window and increase the visibility and usability of the command and monitoring (CMP) panel.

Size

The work volume is 255 liters (~ 9 cu ft.) in volume. The interior dimensions are 934 mm width, 666 mm height, 548 mm lower depth, and 369 mm upper depth. The front of the work volume curves in at the top.

Fluid System

Gaseous nitrogen is available for investigations. Gaseous nitrogen can be connected directly to the investigations via a 1/4 inch quick-disconnect coupling located at the rear wall of the work volume. The MSG does not require gaseous nitrogen itself.

A vacuum vent and vacuum exhaust lines are available for investigations. The vacuum vent is connected directly to the investigations via a 1/2 inch quick-disconnect coupling located on the rear wall of the work volume. The vacuum exhaust is connected directly to the investigations via a 1/2 inch quick-disconnect coupling located on the rear wall of the work volume.

Data Connections

Several data connections are available inside the work volume. Two RS-422 connections are available inside and one outside the work volume. A MIL-BUS-1553B connection is available both inside and outside of the work volume. An analog / digital data system is also available. Eight 16-bit analog and eight digital data acquisition channels can be monitored and downlinked. Eight digital data output channels are available for investigation commanding. All of these data connections are routed through the standard payload computer (SPLC) for downlink and uplink to the ISS data system. This two-way data communication connection with the ISS data system allows for ground commanding of the facility and the investigations. Investigation science data can also be downlinked. Facility health and status data and verification of facility commanding (both from ground and orbit) can also be downlinked. Two medium rate ethernet connections are inside the work volume. They do not pass through the SPLC but are connected directly to station. These ethernet connections are for connecting an investigation or a laptop computer to station for a more direct and faster communication connection with the ground telescience center or other payloads on orbit.

Illumination

At the top inside of the work volume are three banks of lights (left, center and right) which provide the light source for the general illumination system. Each bank has 12 bulbs. Together they can provide a maximum of 975 lux of illumination to the work volume. The

lighting level is variable from 0 up to 975 lux. A spotlight is also available for doing precision tasks that require additional light.

Filtered air

The work volume's air filtration system helps to provide a 100K cleanroom capability. The 12 filters are a three part HEPA, charcoal and catalyst unit. The HEPA removes particles greater than 0.3 microns in diameter. The charcoal filters gases. The catalyst converts carbon monoxide to carbon dioxide.

Power

One Thousand watts of 120 VDC power is available for high power investigations. Two hundred watts of power is available at 28 VDC. Other voltages available are +/- 12 VDC and 5 VDC.

Humidity Control

The work volume is designed to maintain the humidity inside the work volume to between 25 and 70%.

Thermal

The filtered air circulating inside the work volume is passed through an air / water heat exchanger. Then the air is returned to the work volume. The water passing through the heat exchanger is connected to the ISS moderate temperature cooling loop (MTCL). The water from the MTCL first passes through this air / water heat exchanger before continuing on to other components. Thus, the air temperature inside the work volume is expected to very closely follow the temperature profile of the MTCL (approximately 18 to 20 degrees Celsius) if no heat is being rejected inside the work volume. If heat is being rejected inside the work volume, the heat exchanger is sized such that 200 Watts of heat can be removed via filtered air flow. After the filtered air / water heat exchanger the MTCL cooling water flows through a 13 by 15 inch coldplate located in the bottom of the work volume. This coldplate has provisions for investigations directly mounted to it. It can remove 800 Watts of heat with a surface temperature of 50 degrees Celsius. Together, the cooled filtered air and the coldplate can remove 1000 Watts of heat from an investigation. One thousand Watts is the total power available to investigations.

Data System

As mentioned above, the SPLC (and thus MSG) communicates through its MIL-BUS-1553B connection to the ISS. The 1553 passes ground commanding for the facility and investigations to MSG and returns facility health and status and investigation science data from the MSG. Investigations can communicate via MIL-BUS-1553B or RS-422 to the SPLC which processes the information for communication to the ISS. The medium rate ethernet is a direct connection between either investigations or a laptop computer and the ISS. The MSG SPLC is not connected to the ethernet.

A high rate data link (HRDL), (up to 90Mbit/sec); is being used by the MSG video system for downlinking digitized video data. Only video downlinking is performed with the MSG HRDL.

Command and Monitoring Panel

Attached to the top of the work volume is the command and monitoring panel (CMP). The CMP is the man-machine interface for controlling the data system of the MSG. It also is the interface for controlling work volume illumination and work volume air flow rate. Health and status parameters are monitored on a screen and by LEDs. See Figure 4.0 for a graphic drawing of the CMP. Figure 4.0 shows the left half of the panel as the top graphic and the right half of the panel as the bottom graphic.

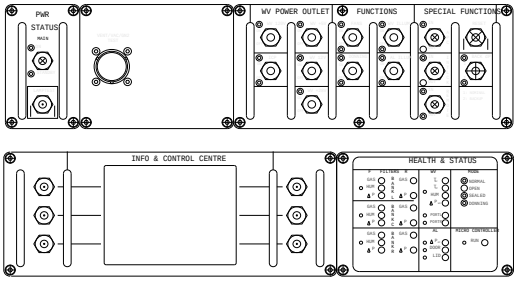

Figure 4.0 MSG Command and Monitoring Panel.

Stowage

Four drawers are located under the work volume for stowage of facility ancillary equipment such as spares and consumables. Stowage for investigations and the support hardware for each investigation will be located outside of the MSG rack.

Airlock

An airlock is provided for transfer of items to the work volume and as a temporary work platform. The airlock is the staging area for the investigations. Its primary function is to ensure that two levels of containment can be provided while transferring items into and out of the work volume while in sealed mode. Features of the airlock include:

Accommodate investigations and equipment module: 25.4 cm x 34.3 cm x 29.9 cm
One 101.6 mm diameter access port
Continuously filtered air
Maintain negative pressure between airlock and ISS cabin
Sealing capability between WV and Airlock
Humidity control: 25- 70%
500 lux illumination
Maximum heat removal 35 Watts
Restraint of items via PIP pins

Standard Payload Outfitting Equipment

Standard payload outfitting equipment (SPOE) are components common to several facilities. These components are developed by others and purchased by the ISS facilities that want to use them. ESA SPOE items include:

Remote power distribution assembly (RPDA)
Rack maintenance switch (RMSA)
Avionics air assembly (AAA)
Standard payload computer (SPLC)

NASA SPOE is the area smoke detector assembly (ASDA).

Video / Audio

The high quality video system has three color cameras and one black and white camera. There are three digital recorders connected to the cameras via a Y/C connection. Two 10 inch color LCD video monitors are mountable either inside or outside of the work volume. The video signals from the cameras or the recorders can also be routed through a computer which digitizes the video for downlinking through the HRDL. A hard disk recorder is also available for frame storing video sequences acting as a time-lapse recorder. The cameras, recorders, monitors, compressor, and time-lapse recorder are all connected to the MSG SPLC to allow the entire system to be controlled from ground. A laptop computer can also be connected to control the video system.

Thermal

After leaving the work volume coldplate, the MTCL cooling water passes through several other components in the rack requiring cooling. Most of these components being electrical or data system items. The only exception being another air / water heat exchanger called the avionics air assembly (AAA) which cools circulating air in the rear of the rack.

Lab Support Equipment

Several pieces of lab support equipment (LSE) are available to investigations. Some of these include:

Compound microscope
Dissecting microscope
Digital multimeter and thermometer
Still camera
Video camcorder
Freezers
Mass measuring devices
pH meters
Cleaning equipment
General purpose tools
Fluid handling tools

Modes of Operation

There are four modes of operation for the MSG: normal mode, sealed mode, open mode and donning mode. Normal mode is when all ports are closed and air is circulating normally in the work volume. Sealed mode is when the work volume ports are closed and no air is circulating in the work volume. Open mode is when the work volume fans are circulating air and a negative pressure is established but the ports are open. Donning mode is the same as normal mode except that the work volume fan speed is maximized to create the greatest negative pressure possible. This allows for the crew person to enter and exit the gloves (don and doff) easier.

Microgravity Environment

The microgravity requirement for the MSG work volume work surface (where most investigations will be performed) must not exceed the vibration levels at the rack mount interface between the MSG and ISS. This requirement applies only when the MSG work volume is retracted and is unattended by the crew. The levels for the rack interface are as follows where f is frequency in Hz:

Frequency Range	RMS acceleration magnitude
0.01-0.1 Hz	< 0.21920 micro-g
0.1-100 Hz	< f * 2.1920 micro-g
100-300 Hz	< 219.20 micro-g

Also, the natural frequency for the first resonant mode of the integrated rack assembly must be greater than 25 Hz. The first natural frequency for mounted equipment must be greater than 35 Hz.

Schedule

The project is currently in the CDR phase. CDR should be completed by spring 1999. Fabrication is to begin immediately following CDR closeout. The ground unit and training units are to be delivered by summer of 1999. The ground unit will be delivered to MSFC and the training unit to JSC. The engineering unit delivery schedule to MSFC is still pending. Launch for the MSG and its first 3 investigations is scheduled for Utilization Flight 1 (UF-1). One investigations is scheduled for UF-2, and 3 investigations for 13A. UF-2 is scheduled for launch in March of 2001. 13A is scheduled for launch in 2002.

Operations

The MSG mission operations will be performed from the MSFC telescience center, building 4493. Pre-mission preparation and post-mission data archiving will originate from this location. Investigators can conduct their mission operations at the telescience center location or remotely from their present research location. Full telescience capabilities are currently being planned for the remotely located investigators.

Personnel

Key personnel for the MSG project includes:

NASA Project Manager: Dave Cockrell, MSFC
NASA Project Scientist: Charles Baugher, MSFC
NASA Project Engineer: Larry Gagliano, MSFC
ESA Project Manager: Bengt Svennson, ESA ESTEC

Acknowledgements

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